Aquatic Ecosystem Health

Aquatic Invasive Species Program

Once introduced and established in park waters, aquatic invasive species are virtually impossible to get rid of.

Yellowstone's world-class fisheries are threatened by introductions of aquatic invasive species (AIS). These harmful, non-native (from elsewhere in North America) and exotic (from another continent) invading species displace precious native species, such as cutthroat trout and many native macroinvertebrates upon which Yellowstone fishes depend for growth and survival. AIS have the potential to impact important trout consumers such as eagles, ospreys, and grizzly bears, causing a disruption of the Greater Yellowstone Ecosystem.

The New Zealand mud snail (*Potamopyrgus antipodarum*) and the parasite that causes whirling disease in trout are examples of exotic AIS that are already present in park waters.[41] The zebra mussel and Eurasian watermilfoil are examples of AIS that are quickly approaching the park, and there are over 300 others now in North America—often so small they are difficult to see.[42] Because AIS are often hidden, they frequently "hitchhike" from one lake or stream to another within the water of a boat bilge or livewell, or in mud, dirt, sand, and plant fragments attached to boats, fishing equipment, or clothing.

During 2004, a resource team convened to develop both short-term and long-term goals for the prevention of additional AIS invasions of Yellowstone National Park waters. Prevention is the key, because once introduced and established in park waters, aquatic invasive species are virtually impossible to get rid of. The following measures have been taken:

- A brochure has been developed to provide information on how to conduct boat inspections and clean angling gear (available online at <www.nps.gov/yell/planvisit/todo/fishing/exotics.htm>).

- Boat ramp signs have been developed and installed at Yellowstone Lake and Lewis Lake ramps.

- Anyone purchasing a boating permit in the park is now asked to watch a video on how to conduct boat inspections for AIS.

The resource team identified several additional "critical control points" that could be used in the future for the prevention of AIS introductions to park waters. These control methods will require a source of funding both for establishment and for long-term maintenance. The long-term goals for AIS prevention include:

- Enhancing public awareness of AIS issues.

- Establishing mandatory boat inspections by trained personnel.

- Establishing boat washing stations.

- Providing facilities for cleaning waders and other angler gear.

- Collaborating with the National Park Service's Vital Signs Monitoring Program to complete an aquatic invasive species risk assessment, and development of monitoring for waters with highest probability of receiving introduced species.

- Collaborating with partner agencies and non-governmental organizations and developing of an Aquatic Invasive Species Management Plan for the Greater Yellowstone Ecosystem.

Yellowstone National Park is a partner in the "Stop Aquatic Hitchhikers" campaign, led by the Aquatic Nuisance Species Task Force and sponsored by the U.S. Fish and Wildlife Service and U.S. Coast Guard.[43] Whenever possible, images and other educational materials common to the campaign are used for purposes of AIS prevention

STOP AQUATIC HITCHHIKERS!™
Prevent the transport of nuisance species.
Clean all recreational equipment.
www.ProtectYourWaters.net

within the park. Additional information can be obtained at <www.protect yourwaters.net> and several other websites.

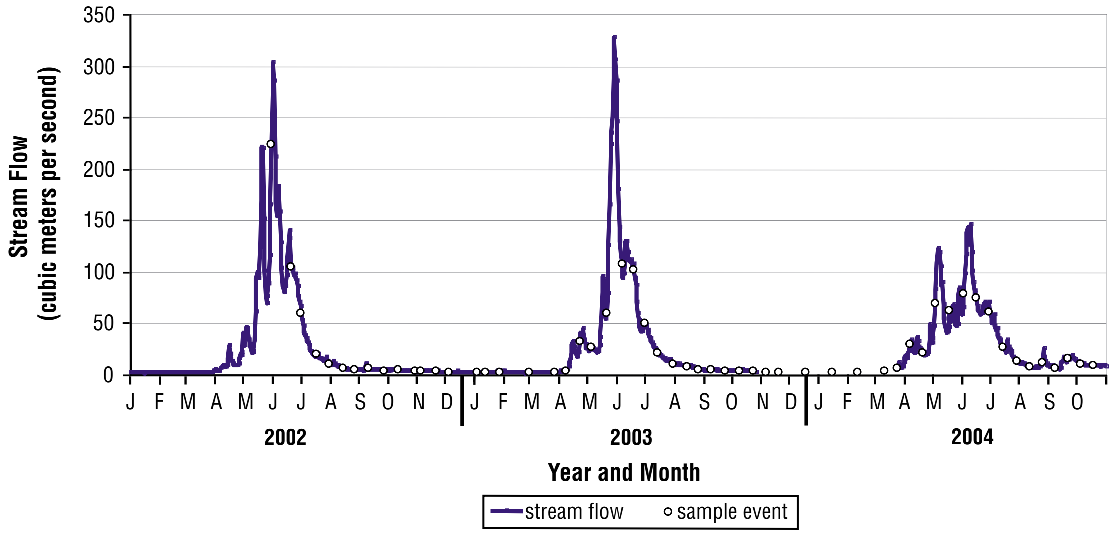

Figure 16. Hydrograph of Lamar River near confluence with Yellowstone River, illustrating mean daily streamflow from 2002 to 2004. Streamflow information was obtained from a U.S. Geological Survey gaging station; open circles represent days when water quality samples were collected.

Long-Term Water Quality Monitoring

During 2004, the Aquatics Section continued to conduct water quality monitoring at 12 established sites on major river basins throughout Yellowstone National Park (Figure 1). Each site was sampled once every two weeks (once each month during winter), with sample days being randomly selected within a sample week. This schedule allowed data to be collected during a variety of flow conditions (Figure 16). A multiparameter probe was used to collect water temperature, dissolved oxygen (DO), pH, specific conductance, and turbidity. Water samples were also collected at each location for total suspended solids (TSS) and volatile suspended solids analysis. These core water quality parameters are important to monitor because they can determine the presence or absence, as well as regulate the distribution and abundance of aquatic organisms. The primary purpose of the water quality monitoring program is to obtain baseline information regarding the health of major streams and rivers within Yellowstone National Park.

The 2004 sample season was characterized by an unusually wet summer and fall period; however, the additional moisture did not translate into higher runoff or increased stream discharge for any of the established water quality sites. In fact, streamflow conditions from gage stations throughout Yellowstone National Park indicated lower flow conditions than in the previous two years (Figure 16). During 2004, most parameters varied considerably within and between sites (Figure 17). Variations among water quality parameters resulted primarily from diurnal cycles, higher flows during spring snowmelt, rain events, seasonal temperature changes, altitude differences, and the thermal influences that affect many streams. Highest mean water temperature of 15.5 degrees Celsius (°C) occurred on the Firehole River (range 7.8–24.0°C), a thermally influenced stream. Lowest mean water temperature of 4.6°C occurred on upper Soda Butte Creek (range -0.1–13.7°C), which is near the park's northeast boundary.

Highest mean DO concentration of 10.7 milligrams/Liter (mg/L^{-1}) was recorded for the Lamar River (range 8.7–13.4 mg/L^{-1}); lowest mean DO concentration of 8.1 mg/L^{-1} was recorded for Pelican Creek (range 2.4–11.0 mg/L^{-1}) (Figure 17). Typically, DO concentrations of less than 5 mg/L^{-1} are considered stressful to most aquatic organisms. Pelican Creek, a slow-moving tributary that enters the northern part of Yellowstone Lake, is characterized by abundant vegetation in the surrounding floodplain. Decomposition of organic matter, coupled with thick ice and snow cover, could be a factor contributing to the low DO reading of 2.4 mg/L^{-1} recorded on December 16, 2003.

Within-site variation of pH was quite low, with most differences occurring between sites (Figure 17). This is best illustrated in the Madison River drainage. The Madison River receives water from the Firehole and Gibbon rivers, both of which are influenced by thermal activity. Mean

Higher turbidity values usually corresponded to spring runoff or localized precipitation events during summer months.

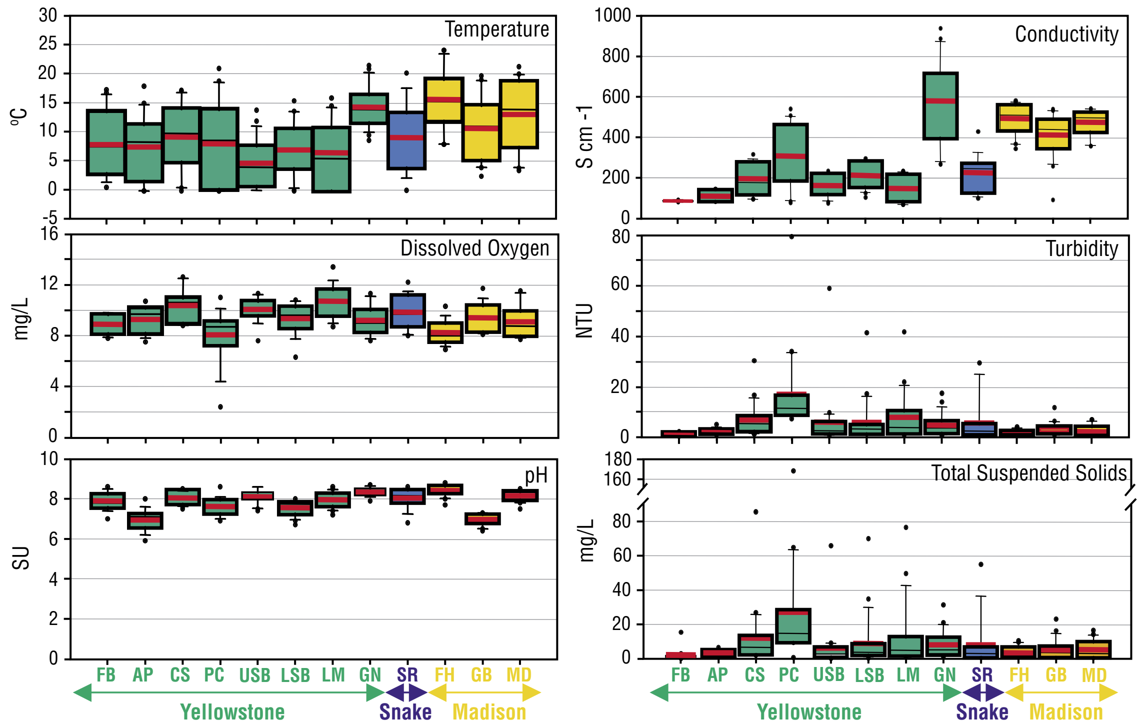

Figure 17. Box and whisker plot illustrating annual variation for selected parameters at each stream water quality location in 2004. Lower and upper portion of boxes represent the 25th and 75th percentile respectively; lower and upper black horizontal bars represent 10th and 90th percentile respectively. Outlining values are represented by black dots; means are indicated by solid red lines. Green, blue, and orange represent the Yellowstone, Snake, and Madison river basins, respectively (FB = Fishing Bridge, AP = Artist Point, CS = Corwin Springs, PC = Pelican Creek, USB = upper Soda Butte, LSB = lower Soda Butte, LM = Lamar River, GN = Gardner River, SR = Snake River, FH = Firehole River, GB = Gibbon River, and MD = Madison River).

pH for the Firehole River was 8.4 standard units (SU) (range 7.7–8.8). This was the highest mean value for all sites sampled, with the exception of Gardner River, which also had a mean pH value of 8.4 (range 7.9–8.7). Conversely, the Gibbon River had a mean pH value of 7.0 (range 6.4–7.3). This river drainage receives considerable runoff from the Norris Geyser Basin, which is typically more acidic than other geyser basins within the park. The Yellowstone River at Artist Point had the lowest mean pH of all water quality sites, with a value of 6.9 (range 5.9–8.0).

Values for specific conductance, turbidity, and TSS were highly seasonal, and appeared to be correlated with river discharge. On average, specific conductivity tended to be lowest during spring runoff and highest during the base flow period of fall and winter months. Additionally, higher specific conductivity values were generally found at sample sites with thermal contributions. For example, the highest mean specific conductivity recorded for all sites sampled were from the Gardner, Firehole, Madison, and Gibbon rivers, with 582.1, 495.3, 475.7, and 413.5 microseimens per centimeter (μS/cm^{-1}) respectively. All of those waterways receive considerable amounts of thermal contributions (Figure 17). Specific conductivity was least variable at the Yellowstone River near Fishing Bridge, and had the lowest mean value of 88.5 μS/cm^{-1} (range 82–94 μS/cm^{-1})(Figure 17). The lowest specific conductivity for all sites sampled was 69 μS/cm^{-1}, recorded at the Lamar River water quality station during a high flow period on June 3, 2004.

Turbidity and TSS are closely linked parameters, both of which evaluate suspended material in the water column. Turbidity is a measure of water clarity, with higher values reflecting a more turbid condition (i.e., less-clear water). It is important to measure because increases in turbidity can negatively affect aquatic plants (reduce photosynthesis) and animals (influence feeding behavior of visual predators). Turbidity is caused by suspended particles present in the water column such as clay, silt, and plankton. In Yellowstone National Park, higher turbidity values usually corresponded to spring runoff or localized precipitation events during summer months. Most sites had mean turbidity measurements below 10 nephlometric turbidity units (NTU), with the exception of Pelican Creek, which had a mean turbidity measurement of 17.1 NTU (range 7.5–79.5 NTU) (Figure 17). The lowest mean turbidity measurement of 1.4 NTU was recorded for the Yellowstone River at Fishing Bridge, which is located just downstream of Yellowstone Lake.

TSS is important to monitor because it is a quantitative measure of the total fraction of inorganic (i.e., clay, silt, and sand) and organic (i.e., detritus and plankton) material suspended in the water column. Increases in TSS, primarily in silt and sand, can lead to sediment deposition in the streambed, increasing stream embeddedness and resulting in a decrease of benthic productivity and the loss of fish habitat. Concentrations of TSS at stream sites mirrored turbidity readings. The highest mean TSS was recorded for Pelican Creek, with a mean of 27.2 mg/L^{-1} (range 0.9–168.6 mg/L^{-1}). The lowest mean TSS was recorded for Fishing Bridge, with a mean concentration of 2.3 mg/L^{-1} (range 0.4–15.5 mg/L^{-1}).

Water Quality Associated with Winter Road Use

During spring 2004, we collected snowmelt runoff from four sample locations within Yellowstone National Park. Snowmelt runoff was sampled for concentrations of volatile organic compounds (VOC). VOCs in snowpack are most likely produced by the incomplete combustion of gasoline from two-stroke snowmobiles. At high enough levels, VOCs can have adverse effects on aquatic organisms.[44] This study was initiated to determine if VOCs were present in snowmelt and, if so, whether there was a possible link to snowmobile use. This was the second year of a two-year study.

Sampling began after the end of the 2003–2004 winter season, March 20–April 3, 2004.

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Ecologist Jeff Arnold samples water quality at Pelican Creek.

Between six and ten water samples were collected from each of the sample locations, which were located in the road corridor between the West Entrance and Old Faithful. Three test sites were established within this area, with one site each in the vicinity of the West Entrance, Madison Junction, and Old Faithful. Each site was selected based on its proximity to the groomed roads used by snowmobiles during the winter season. A fourth site was used as a control located near Madison Junction, on a small, intermittent stream approximately 100 meters from the road.

Sample analysis was conducted by the U.S. Geological Survey's laboratory in Denver, Colorado. Nine compounds within the VOC category were analyzed, including benzene, ethylbenzene, ethyl tert-butyl ether, isopropyl ether, m-xylene/p-xylene, methyl tert-butyl ether, o-xylene, tert-pentyl methyl ether, and toluene. Similar to the 2003 results, only five of these compounds were detectable within any given sample (benzene, ethylbenzene, m-xylene/p-xylene, o-xylene, and toluene). Samples of snowmelt runoff near Old Faithful contained all five compounds during at least one sample event. The maximum concentration for these five compounds detected near Old

Although VOCs were found at several sample locations, the concentrations of these compounds were well below the U.S. Environmental Protection Agency's level of toxicity to aquatic organisms.

Faithful were (units are in µg/L^{-1}): benzene, 0.026 (estimated); ethylbenzene, 0.720; m-xylene/p-xylene, 3.365; o-xylene, 2.183; and toluene, 1.008. Only two VOC compounds (m-xylene/p-xylene, and toluene) were detected from snowmelt runoff near the West Entrance site, which is in contrast to 2003, when all five compounds were identified there. Both m-xylene/p-xylene and toluene were found in very low concentrations, with maximum estimated values of 0.008 and 0.037 µg/L^{-1}, respectively. VOCs were not detected in any test sample from the Madison Junction site. Water samples from the control site did contain trace levels of toluene during three sample visits, which was comparable to the 2003 results. These are similar to results of previous investigators who have also found measurable levels of toluene at off-road locations during spring snowmelt sampling.[45] Currently, the source of toluene at off-road locations is not known. Although VOCs were found at several sample locations, particularly Old Faithful and the West Entrance, the concentrations of these compounds were well below the U.S. Environmental Protection Agency's level of toxicity to aquatic organisms.[46] In addition, once the snowmelt enters a larger body of water, the dilution of the VOCs will be even more pronounced. Thus, given the volatile nature of these compounds and the low concentrations present in the test samples, it is unlikely that these chemicals will adversely affect aquatic organisms.

Water Quality Monitoring Goals

Future goals for the water quality program are to continue monitoring at the 12 established sites on major river basins of the park (Figure 1) to acquire baseline information and determine inter- and intra-annual variation of basic, water quality core parameters. In addition, through collaboration with the National Park Service Vital Signs Monitoring Program, we will begin focused water quality sampling of the park's state 303d-listed streams (Soda Butte Creek and Reese Creek). We are also working on the development of a probabilistic sampling design for macroinvertebrates and water quality at a large spatial scale. The protocols to be used will be consistent among the three parks of the Greater Yellowstone Network, and will allow for the comparability and consistency required for tracking long-term changes (decades or longer) in the health of Yellowstone's aquatic systems.

Yellowstone Lake Limnology

Collection and analysis of physical and chemical parameters is a crucial component in understanding the limnology of Yellowstone Lake. These parameters have a tremendous influence on abundance and distribution of aquatic organisms. In particular, these data will provide park fisheries biologists with important information regarding movement patterns of lake trout while gillnetting operations are underway. For example, during summer months when the thermocline (area in water column of greatest temperature change) becomes established, lake trout generally move into deeper, cooler waters avoiding the warmer water near the lake surface.

The seven long-term water quality monitoring sites on Yellowstone Lake were sampled from May 21 through October 20, 2004 (Figure 3), with data being collected every two weeks. During each sample event, water temperature, DO, pH, specific conductance, and turbidity measurements were made using a multiparameter probe near the lake's surface at a depth of 0.2 m. Surface water was also collected at each location for TSS and volatile suspended solids analysis. To obtain a more comprehensive understanding of Yellowstone Lake limnology, we collected depth profile information from all sites when weather permitted. The multiparameter probe was used to collect water temperature, DO, pH, and specific conductance at various depths throughout the water column from each sample location.

Mean surface water temperature, DO, pH, and specific conductance values were fairly consistent among all seven sample locations. Surface water temperatures reflected seasonal changes, with lower temperatures occurring during the spring and fall, and higher temperatures occurring during the summer months. The highest mean surface water temperature of 11.2°C (range 4.5–17.5°C) was recorded at the Mary Bay site;

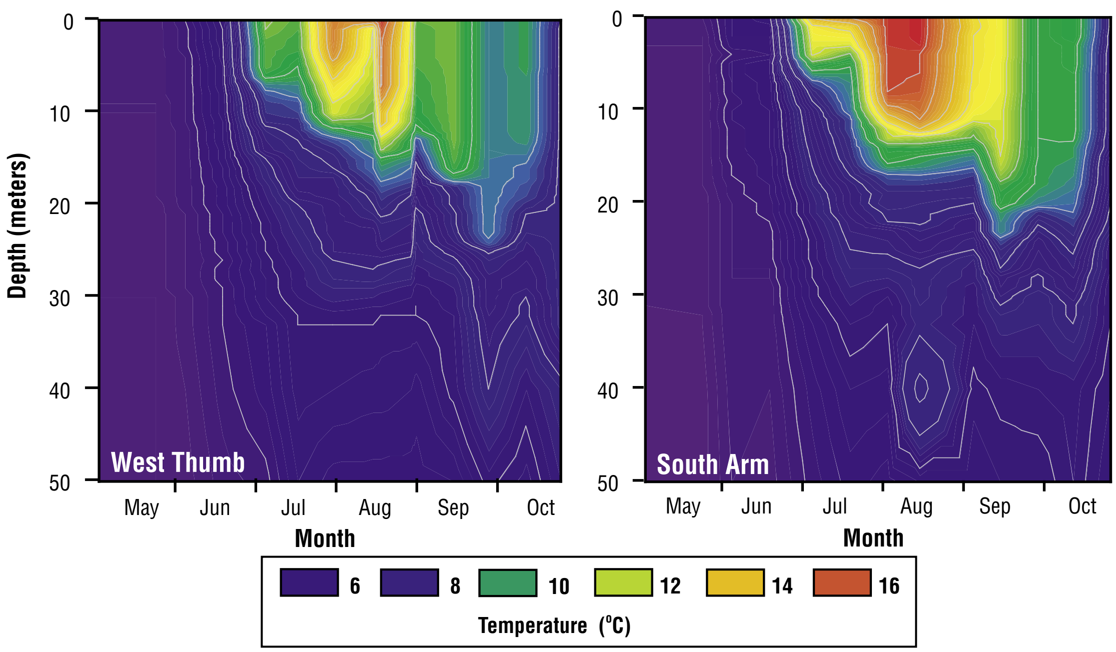

Figure 18. Isopleth of water temperature in West Thumb and South Arm of Yellowstone Lake during summer 2004. Contour lines represent one-degree intervals. For comparison, and greater resolution of surface temperatures, only data from the first 50 meters is displayed for the West Thumb location.

the lowest mean surface water temperature of 9.7°C (range 4.5–15.2°C) was recorded at the West Thumb site (Figure 18). The slightly cooler water temperatures recorded for the West Thumb site are likely the result of its being sampled prior to noon on most sample days. Data from the water temperature depth profiles indicated that the water temperature remained fairly constant throughout the water column, about 4°C, until mid-June, when surface water temperatures began to rise. The lake began to stratify by early July, with the development of the thermocline, which became established at approximately 20 m by mid-September (Figures 18 and 19).

Surface water DO concentrations on Yellowstone Lake, for all sites combined, ranged from 7.4 to 10.7 mg/L^{-1} throughout the 2004 season. Trends in DO concentrations were similar among all sites, with lower values being recorded during the summer months (July and August) when surface water temperatures were warmest, and higher values being recorded during the spring months (May and June) when surface water temperatures were coolest. Mean DO concentrations were similar among all sites, with values ranging between 8.6 and 8.8 mg/L^{-1}. Examination of the depth profile data indicated that DO concentrations remain comparatively consistent throughout the water column for any given sample day (Figure 19).

Surface water pH values were less variable between sites and throughout the season. The highest mean pH value of 8.0 (range 7.5–8.3) was recorded for the South Arm site; the lowest mean pH value of 7.6 (range 7.3–7.9) was recorded for the Mary Bay site. The subtle differences in pH values among and between sites can most likely be attributed to natural variability throughout the lake basin.

Specific conductivity values varied little during the season and between sites. Overall, mean specific conductivity values for all sites ranged from 84 to 94.4 µS/cm^{-1}. The highest mean specific conductivity value of 94.4 (range 92–96 µS/cm^{-1}) was recorded for the West Thumb site; the lowest mean specific conductivity value of 84 µS/cm^{-1} (range 69–91 µS/cm^{-1}) was recorded for the Southeast Arm site. The slightly higher values in the West Thumb area may likely be linked to the large amount of thermal activity within the basin. The lower specific conductivity values recorded for the Southeast Arm are most likely associated to the lower specific conductivity of the upper Yellowstone River, which enters Yellow-

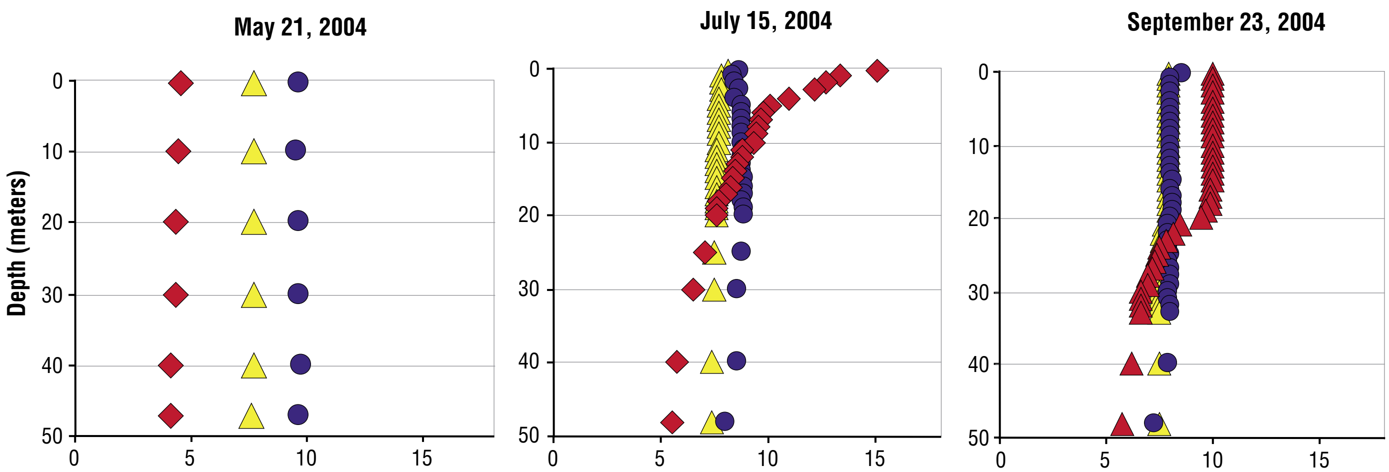

Figure 19. Water temperature (red), pH (yellow), and dissolved oxygen (blue) values in relation to depth and season in South Arm of Yellowstone Lake, 2004.

stone Lake just south of the sample location.

As with stream sampling, turbidity and total suspended solids are closely linked parameters that measure the amount of material present in the water column. Mean turbidity measurements were quite low for all sites. The highest mean turbidity of 1.6 NTU (range 0.4–6.0 NTU) was recorded for the Southeast Arm site; the lowest mean turbidity measurement of 0.5 NTU (range 0.3–1.0 NTU) was recorded at the Stevenson Island site. The slightly higher mean turbidity in the Southeast Arm could be attributed to suspended material entering Yellowstone Lake via the upper Yellowstone River. Measurements of TSS in Yellowstone Lake primarily reflect the organic (plankton) material present in the water column. As with turbidity, TSS measurements for all sites were quite low throughout the season. The highest mean TSS measurement of 0.097 mg/L^{-1} (range 0–0.212 mg/L^{-1}) was recorded for the Mary Bay site; the lowest mean TSS measurement of 0.039 mg/L^{-1} (range 0–0.091 mg/L^{-1}) was recorded for the West Thumb site.

Macroinvertebrates as Health Indicators

Effective water quality monitoring requires a combination of physical, chemical, and biological measurements to efficiently evaluate the health of aquatic systems. Physical and chemical measurements directly measure parameters within the stream channel and water column; biological measurements evaluate the response of organisms (e.g., periphyton, aquatic invertebrates, and fish) to changes within their environment. Sampling aquatic invertebrate communities continues to be a practical method of evaluating stream health in Yellowstone National Park. These organisms are ideal biological indicators because they are sensitive to environmental changes (physical and chemical), relatively immobile (as compared to fish), generally have long life spans (1–2 years), and are easy to sample. Accordingly, by studying aquatic macroinvertebrate communities within a given stream segment, we can assess the current water quality condition of that stream. Additional water quality information that is collected with invertebrate sampling includes a habitat assessment and collection of basic water quality parameters such as water temperature, dissolved oxygen, pH, specific conductance, turbidity, and stream discharge.

During 2004, we continued to collect aquatic macroinvertebrates as part of the Aquatic Section's aquatic ecosystem health program. Macroinvertebrate monitoring was conducted in response to a variety of factors that currently threaten the health of aquatic resources within the park. For example, the ongoing road construction projects are continual concerns to park resource managers. Many roads within the park are decades old, and in various stages of disrepair. These roads often parallel stream and river corridors. As a result, renovation of these roads poses potential risks to aquatic systems through sedimentation and stream channel alteration. In relation to ongoing or future road construction projects, we sampled 17 sites on 10 stream segments. Streams (and number of sites) selected for sampling were: Antelope Creek (1), Alum Creek (1), Elk Antler Creek (1), Gardner River (1), Gibbon River (4), Middle Creek (2), Obsidian Creek (4), Otter Creek (1), Pelican Creek (1), and Trout Creek (1) (Figure 1). Data collected from these sites will help park resource managers better understand the impacts, if any, that road reconstruction has on water quality, specifically effects on aquatic biota. Additionally, a long-term macroinvertebrate site on upper Soda Butte Creek near the park's northeast boundary was sampled. This site is sampled annually to monitor any possible effects that the McLaren Mine tailings, located upstream of the park boundary near Cooke City, Montana, may have on the water quality of Soda Butte Creek within park boundaries. This is the third consecutive year that aquatic benthic macroinvertebrates have been collected at this location. Samples collected for these projects are currently being analyzed, with results becoming available during spring 2005.

Invertebrate samples were also collected as part of the westslope cutthroat trout restoration project currently underway in the Specimen and Fan creek drainages. During August 2004, we sampled six invertebrate locations throughout the Specimen Creek drainage to evaluate current water quality conditions. These data will also provide necessary background information regarding inventory and distribution patterns of aquatic invertebrate assemblages needed prior to any fish restoration attempt there. Samples collected from the Specimen Creek drainage are being analyzed, with data expected to be available in summer 2005.

In response to an accidental fire retardant drop that occurred in the Bacon Rind Creek drainage during September 2003, we conducted invertebrate sampling to examine potential impacts the spill had on stream water quality. Most fire retardants, as was the case with the Bacon Rind spill, contain high concentrations of ammonia, which is toxic to most plants and animals. The initial site inspection, which occurred during October 2003, concluded that the main volume of fire retardant was dropped approximately 90 m from Bacon Rind Creek. By examining the spray pattern on materials near the stream channel, it was also determined that approximately 33% of the stream surface area within a 20-m reach was affected by the fire retardant. To evaluate the effects of fire retardant on stream water quality and aquatic biota, we collected invertebrates from two stream segments, one downstream and one upstream of the impacted area. Eight surber samples (0.09m^2, 500-µm mesh) were collected from each stream segment. To reduce variability, samples were collected from areas with similar instream habitats, gradients, and steamflow. Preliminary results indicate that the area immediately downstream of the fire retardant drop may have been mildly impacted by the fire retardant. Fifty-six unique taxa were collected from the downstream reach, compared to the 64 taxa collected from the upstream reach. Additionally, the number of intolerant taxa (groups of organisms that are not tolerant of environmental pollutants) was slightly lower at the downstream location (10 taxa) than the upstream location (12 taxa). However, the Hilsenhoff Biotic Index, which evaluates tolerance levels of benthic macroinvertebrates to pollutants, scored both of these stream segments as being in excellent condition. If the fire retardant had any impacts on the water quality of Bacon Rind Creek, they appeared to be short term, with no significant adverse effects on aquatic biota.

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Bacon Rind Creek at the site of an accidental fire retardant drop during September 2003.

Disease Surveys

Fish Health Surveys

The Aquatics Section continues to participate in the U.S. Fish and Wildlife Service National Wild Fish Health Survey to monitor the physical health of sampled fish populations that have not yet had a population-level health diagnosis. According to the established protocols, a subsample of fish collected by fishery personnel were lethally sampled and examined for a variety of parasitic infections and bacterial and viral diseases. Through collaboration with the Bozeman Fish Health Laboratory, approximately 26 sites within Yellowstone National Park have been examined by the Survey (1995–2004), with many additional sites examined in the Yellowstone Lake drainage as part of the park's whirling disease research program (Figure 20). To date, we have documented the presence of two significant fish pathogens within the park:

- *Renibacterium salmoninarum*, the agent of bacterial kidney disease, and

- *Myxobolus cerebralis*, parasite responsible for salmonid whirling disease

R. salmoninarum was confirmed by DNA polymerase chain reaction (PCR) from several waters, including Canyon, Fan, and Soda Butte creeks, the Gardner, Gibbon, and Firehole rivers, and Yellowstone Lake. It is suspected that several other streams harbor the pathogen, but its presence was not confirmed with PCR. There have been no documented fish population declines due to this pathogen in the park, and it is suspected that the pathogen may be endemic to the region. *M. cerebralis* was confirmed by PCR from the Firehole River and several locations in the upper Yellowstone River drainage above the Upper Falls. This parasite is an introduced, exotic species native to Europe, and it has resulted in severe declines in native cutthroat trout and other fish species in the intermountain region.

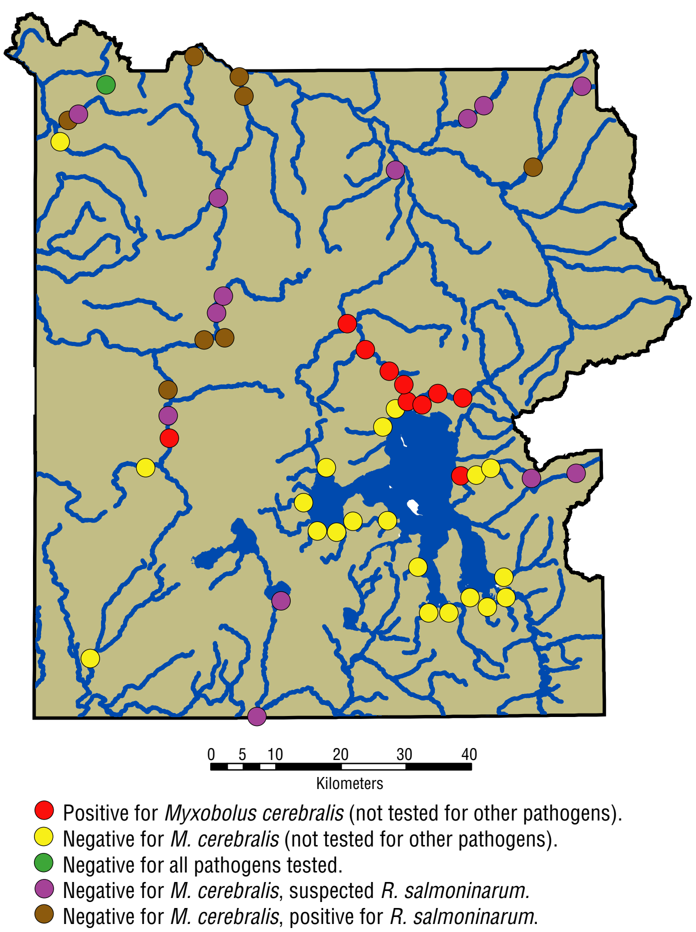

Figure 20. Stream sites examined by the U.S. Fish and Wildlife Service, Wild Fish Health Survey or by sentinel cutthroat trout fry exposures, 1995–2004. Sites that tested positive for the presence of Myxobolus cerebralis (Mc)*, the cause of whirling disease, are in red.*

Whirling Disease and its Effects on Cutthroat Trout

In Yellowstone National Park, research on the native Yellowstone cutthroat trout of the Yellowstone Lake basin has provided strong evidence that this subspecies and strain is extremely susceptible to *Myxobolus cerebralis* (*Mc*), the parasite that causes whirling disease. Up to 20% of all juvenile and adult Yellowstone cutthroat trout within the lake are infected. Sentinel exposure studies (in which uninfected fry are held within cages in a stream and later examined for exposure to whirling disease) suggest that risk of infection is highest in the Yellowstone River and Pelican Creek (the second largest tributary to Yellowstone Lake). Average infection grades in this stream have been 4–5 on the MacConnell-Baldwin scale (0 = no infection to 5 = worst possible infection). Additionally, recent studies have examined the genetic composition of *Tubifex tubifex* (Oligochaeta: Tubificidae) in the Yellowstone Lake basin. Results indicated that at least some of the *T. tubifex* are similar to those from the Madison River in Montana, a clade that is moderately susceptible to the parasite.[47]

The following is a timeline of *Mc* examinations within Yellowstone National Park during the decade following the 1994 discovery of *Mc* (and 70–90% decline) in rainbow trout of the nearby Madison River:[48]

1995–1998 following the discovery of the parasite in the Madison River of Montana, fish from Yellowstone's "boundary area" streams, thought to be most vulnerable, were tested for *Mc.*

1998 (October) *Mc* is unexpectedly confirmed from deep in the interior of the park, in cutthroat trout collected within Yellowstone Lake near the mouth of Clear Creek.

1999 juvenile and adult cutthroat trout are found to have *Mc* at locations throughout Yellowstone Lake.

1999 sentinel exposure studies begin on Yellowstone Lake tributaries, with the Yellowstone River at Fishing Bridge testing positive for *Mc.*

2000 multiple exposure period studies begin on Yellowstone Lake tributaries, with *Mc* detected at Clear Creek (slight, a single fry) and Pelican Creek (severe).

2000 *Mc* confirmed in a single rainbow trout from the Firehole River.

2001 sentinel exposure studies continue, oligocheate surveys are initiated, and actinospore release studies are conducted, as are *T. tubifex* genetics investigations. At least two other myxozoans are also infecting fishes of the Yellowstone Lake basin.

2002 intensive research begins on Pelican Creek, Clear Creek, and the Yellowstone River downstream of Fishing Bridge. *Mc* is confirmed at sites as far upstream on Pelican Creek as the old bridge crossing; no further spread to other tributaries is noted.


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Fisheries technician Shane Keep checks a whirling disease sentinel cage in the upper Pelican Creek watershed during 2004.

2003 testing continues on Yellowstone Lake, its tributaries (especially those with characteristics similar to Pelican Creek), and at streams throughout the park. *Mc* confirmed downstream in the Hayden Valley reach of the Yellowstone River.

2004 intensive research begins to examine the tubificids of the Pelican Creek watershed in an effort to look for ways to mitigate the disease. Severe *Mc* infection risk is confirmed at remote, upstream sites within the watershed through sentinel fry exposures and tubificid surveys.

2004 research is undertaken to examine the role of American white pelicans as dispersal vectors for *Mc* in the region.

2004 testing by Montana Department of Fish, Wildlife and Parks locates a severe *Mc* infection in Cougar Creek, an upstream tributary of the Madison River (Hebgen Lake).

By 2001, cutthroat trout sentinel fry exposures confirmed the presence of *M. cerebralis*

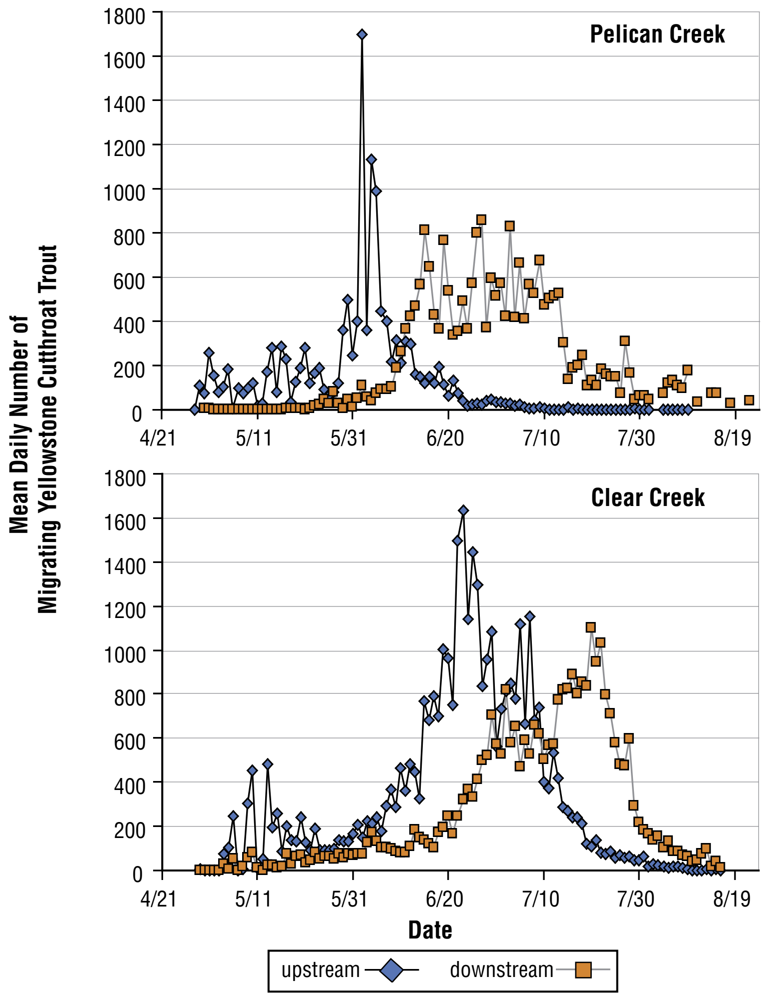

Figure 21. The mean daily number of Yellowstone Lake adfluvial Yellowstone cutthroat trout that were enumerated at migration traps while moving upstream and downstream in Pelican Creek (1964–1983) and Clear Creek (1977–2001).

in three important Yellowstone Lake spawning streams: Pelican Creek, Clear Creek, and the Yellowstone River downstream from the lake outlet (Figure 1).[49] Since then, sentinel exposures in the Yellowstone River upstream of the lake inlet and 13 other spawning tributaries have failed to detect the presence of this exotic parasite. The impacts of *M. cerebralis* were most severe in Pelican Creek, where few wild-reared fry have been observed in recent years (2001–2004). Because of this, we began looking for spawning cutthroat trout each spring. Consistent, annual counts of upstream-migrating adult cutthroat trout were not made in Pelican Creek in recent years, but records exist from a historical weir that was used to enumerate spawning fish through 1981.[50] Historical records indicated that most cutthroat trout migrated up Pelican Creek from mid-May through the third week in June, with peak migration occurring during the first week of June (Figure 21). The spawning migration at Clear Creek, the tributary where *Mc* has only been found one time in a single fry, has generally occurred a few weeks later in the year, with a bi-modal spawning peak typically occurring during the third week in June. Downstream movements of adult fish returning to Yellowstone Lake from Pelican Creek occurred from mid-June through mid-July; from Clear Creek, they occurred from late-June through late-July. This variation in timing of cutthroat trout spawning may, to some extent, explain the differences in *Mc* infection we have noted among these tributaries.

Netting near the location of the historical weir on Pelican Creek (near the tributary mouth) for upstream-migrating adults in 2002–2004 indicated that the spawning cutthroat trout population of this tributary, which in 1981 was nearly 30,000 fish, has been essentially lost. With a drainage area of 17,565 ha, Pelican Creek is the second-largest tributary to Yellowstone Lake in terms of discharge (the Yellowstone River upstream of Yellowstone Lake has the largest drainage area). Establishment of *Mc* has likely contributed to the severe decline of cutthroat trout within Pelican Creek, and the overall population decline within the Yellowstone Lake ecosystem. Fry and fingerling cutthroat trout found in remote, upstream tributaries of Pelican Creek during 2004 provide hope, however, that at least some fish in this drainage are avoiding the disease, and may one day give rise to higher numbers of cutthroat there.

Work on *Mc* is now focused on Pelican Creek, where the infection consistently has been most severe. Infection risk of native Yellowstone cutthroat trout is being related to *Tubifex tubifex* (the alternate host for *M. cerebralis*) presence, abundance, and infection, and the environmental characteristics of sites within the Pelican Creek watershed. Prior to 2004, severe infection was documented through exposure of Yellowstone cutthroat trout fry to the trail crossing (near the old bridge site) far upstream on Pelican Creek. In 2004, for the first time, we conducted exposure studies in the upper reaches of the drainage, including the unnamed tributary that originates on Mount Chittenden (Creek 10851100), Raven Creek, and the mainstem of Pelican Creek just below the confluences with these streams. Ten-day exposures beginning on August 31 and September 10, followed by incubation of the fry in aquaria for three months, indicated some of the highest whirling disease infection risk ever found within the park. All three sites in this area resulted in a mean histological score for infection severity of 5.0. These fry also tested positive for *Mc* by PCR analysis, as did fry exposed experimentally for only 24 hours that were immediately sacrificed. The 24-hour exposures were conducted in an attempt to find a more efficient way of determining *Mc* prevalence in remote streams like Pelican Creek. Analyses of caudal, anal, or pectoral fins, or skin scrapes of these exposed fry, all proved to have potential for use in the future.[51] Because the fry are sacrificed on site, instead of being transported out of the backcountry alive and held for months in laboratory aquaria, the 24-hour technique saves great amounts of time and expense. A trade-off, however, is that the severity of the infection cannot be assessed with this technique, because the parasite is not allowed to develop for histological examination.

A large-scale investigation of *Tubifex tubifex* was launched in 2004, as part of our continued attempts to understand whirling disease in Yellowstone, in close collaboration with the Department of Ecology, Montana State University. Preliminary DNA results of 5,804 oligochaetes collected at 25 sites and examined by PCR in 2004 suggested that the parasite extends far upstream in the watershed.[52]

Additionally, we have been interested in learning about how *Mc* might have originally been introduced to Yellowstone's waters, and ways this parasite might be moving within the park, infecting additional streams in the future. Movement of infected hatchery fish has been blamed for the spread of *Mc* in Colorado, and its introduction to Wyoming, but fish have not been stocked (legally) in the Yellowstone River drainage within Yellowstone National Park since 1955, prior to the first discovery of whirling disease in the United States. The vector for dissemination to many waters of the Intermountain West, including the relatively pristine and highly protected waters of Yellowstone Lake, is unclear. The risk of *Mc* spread to additional waters within the Greater Yellowstone Ecosystem, where fish are not being introduced by humans, is equally unclear. Obvious potential vectors include the movement of myxospores by humans (anglers and their gear) or by fish-eating wildlife, especially those capable of traveling long distances in a short period of time, such as avian piscivores.

The wide spatial extent of *Mc* found within the Pelican Creek watershed suggests that movement of this parasite has occurred, to some extent, by vectors other than anglers. To examine the potential of *Mc* movement by fish-eating birds, we collected 500 white pelican fecal samples from the Molly Islands (in Yellowstone Lake's Southeast Arm) during August 2004, for development of an extraction technique and testing for the presence of *Mc* DNA by PCR. Results from the initial analyses of these fecal samples suggested that *Mc* was not present. However, only a small portion of each fecal sample was examined. We are now working to refine the extraction techniques to include the entire fecal sample and ensure that any *Mc* myxospores that may be present are isolated and analyzed.[53] Our goals for this research in 2005 are to examine the potential of

BETH MACCONNELL

Yellowstone National Park supervisory fisheries biologist Dr. Todd Koel and fisheries biologist Dan Mahony with the fisheries horses Pat, Ethan, Scotty, Sammy, and Mother (L to R) at Pelican Springs cabin in August 2004.

A better understanding of how *M. cerebralis* is dispersed may help us to prevent introductions to additional Yellowstone waters in the future.

NPS/TODD KOEL

American white pelicans of the Molly Islands colony are being examined to gauge their potential to transport whirling disease.

other birds to be *Mc* dispersal vectors, including great blue herons and double crested cormorants. Fish infected by *Mc* will be fed to captive birds, and viability of spores will be assessed following passage through the alimentary canal of these bird species. Companion research is being conducted by Montana State University and the U.S. Geological Survey's Montana Cooperative Fishery Research Unit to examine the possible role of anglers as dispersers of *Mc.* A better understanding of how *Mc* is dispersed may help us to prevent introductions to additional Yellowstone waters in the future.

Amphibian Loss Near Fishing Bridge

Two major infectious diseases were found in Yellowstone National Park amphibians in 2004: one from specimens collected during monitoring, and the other from a mortality event (die-off) of spotted frogs at a small tributary to the Yellowstone River north of Fishing Bridge in 2002. This stream happens to be an outflow of the Fishing Bridge sewage treatment plant. From examination of amphibians found in several areas in the park in 2000–2002, pathologists at the USGS National Wildlife Health Center in Madison, Wisconsin, confirmed the presence of ranavirus and chytridiomycosis.[54] Both diseases were found in dead or moribund adult spotted frogs collected at Chipmunk Creek and Creek 1082, tributaries to Yellowstone Lake. Chytridiomycosis is caused by a fungus parasitizing the skin of adult amphibians, and is a known cause of amphibian population declines elsewhere. Ranavirus typically affects larval amphibian populations. The discovery of lethal outbreaks in adult spotted frog populations was described by the USGS pathologist as extremely rare and noteworthy.

It was also discovered that a parasite of cutthroat trout affects frogs. Encysted metacercaria of trematodes (family *Diplostomatidae,* genus and species not identified) resulted in abnormalities in most of the young-of-the-year spotted frogs inhabiting the mouth of Lodge Creek in August–September 2003. This type of parasite has loose host specificity for the first and second intermediate hosts. Fish kills due to the parasite have been reported in small, young fish. Salmonid and sucker species are heavily infected in some areas, including Yellowstone Lake and the Madison River. In 2004, no abnormal frogs were found at lower Lodge Creek, but young-of-the-year frogs were nearly absent despite abundant egg production in May.

The cause and ability of these disease events to persist is unknown, but this work highlights the fragility of these unique fauna, even within the highly protected environment of Yellowstone National Park.

Trends from the Volunteer Angler Report Cards

Angling remains a popular pastime for those visiting, living near, and working in Yellowstone National Park. An estimated 51,542 people fished in park waters during 2004. Most anglers purchasing a special use fishing permit (required for fishing in park waters) receive a volunteer angler report (VAR) card. These cards have been distributed since 1973, and provide anglers an opportunity to share their fishing success and opinions about the fisheries with park fisheries managers. There was a response of more than 3,000 angler outings through the VAR program in 2004.

Park fisheries managers use the information provided by VAR cards to get an overview of angler use, fish population dynamics, and attitudes toward the fisheries resources of Yellowstone National Park. Data from 2004 indicated that anglers fished for an average of 2.87 hours per

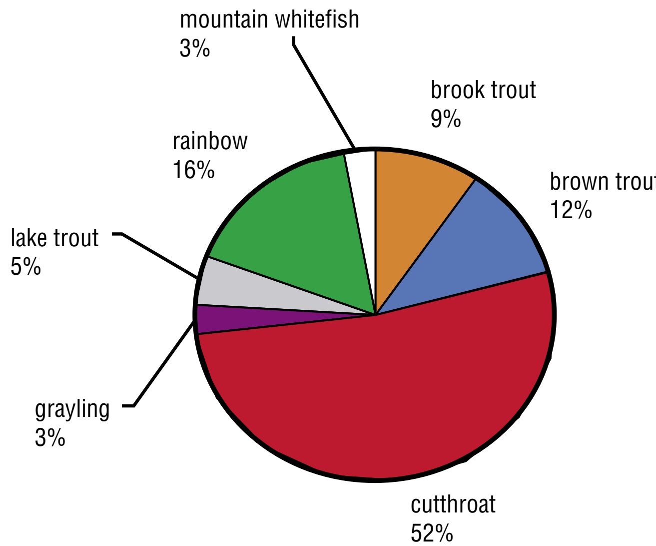

Figure 22. Total angler-reported catch for each fish species in Yellowstone National Park during the 2004 fishing season.

CHARLES WALTON

Yellowstone cutthroat trout is the most highly sought after species by anglers visiting Yellowstone National Park.

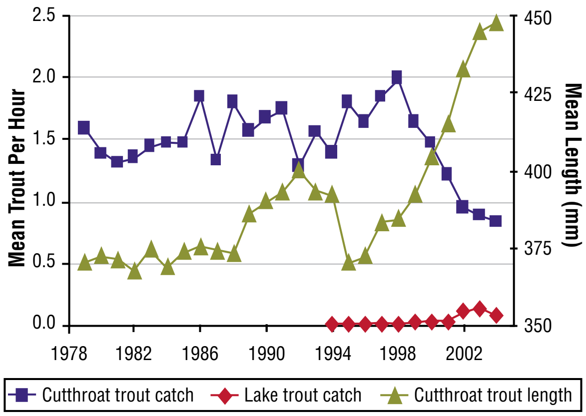

Figure 23. Angler-reported catch rate for cutthroat trout and lake trout, and the average length of cutthroat trout caught by anglers from Yellowstone Lake, 1979–2004.

day during a typical outing, and fished 1.69 days during the season. Sixty-two percent of anglers fished only one day, and accounted for 82% of fish caught. Only 5.1% of these anglers kept fish. Anglers reported being satisfied with the overall fishing experience (76%), with the number of fish caught (62%), and with the size of fish (68%).

Anglers caught an estimated 606,521 fish in Yellowstone National Park during the 2004 fishing season. Native cutthroat trout remained the most sought-after and caught fish species, comprising 52% of the total catch, followed distantly by rainbow trout 16%, brown trout 12%, brook trout 9%, lake trout 5%, mountain whitefish 3% and grayling 3% (Figure 22).

Yellowstone Lake remained the most popular destination for anglers; an estimated 10,326 anglers fished Yellowstone Lake in 2004, representing one quarter of all fishing effort in the park. Anglers fishing Yellowstone Lake reported catching 0.83 cutthroat per hour of fishing. This catch rate is less than in recent years, and follows a five-year downward trend since a record high in 1998. The average length of cutthroat caught by anglers increased again in 2004, to 448 mm (17.7 inches), and is at an all-time high (Figure 23).

In the effort to decrease lake trout in Yellowstone Lake, the park encourages anglers to fish for lake trout, without limitations on size or numbers. In fact, anglers are required to kill all lake trout they catch in Yellowstone Lake. An estimated 8,465 lake trout were caught by anglers in Yellowstone Lake during the 2004 angling season. The angler-reported catch rate for lake trout in Yellowstone Lake decreased in 2004, to 0.13 fish per hour. This is the first year since 1998, and the second year since their discovery in Yellowstone Lake that the angler catch per effort has decreased, and is a positive sign that the effort to reduce lake trout is achieving some success.

The Aquatics Section will continue to use the VAR cards as a tool to gauge fish population trends, use of waters, and visitor enjoyment of the tremendous fishing opportunities that exist in Yellowstone National Park.

NPS/TODD KOEL

Lake Yellowstone and the upper Yellowstone River.

Yellowstone Volunteer Flyfishing Program

Although Yellowstone's fisheries staff have directed much of their efforts at emerging crises such as lake trout removal and whirling disease in recent years, there are a multitude of other fisheries issues and questions that need attention. There are an estimated 2,650 miles of streams and 150 lakes with surface waters covering 5% of Yellowstone's 2.2 million total acres. Because National Park Service staff cannot address all of the park's aquatic issues, a program was established to incorporate flyfishing volunteers to use catch-and-release angling as a capture technique for gathering biological information on fish populations throughout the park. In 2004, the Volunteer Flyfishing Program was coordinated by Dr. Timothy Bywater and Mr. Bill Voigt, both avid flyfishers and long-time supporters and promoters of Yellowstone's fisheries. Projects included:

- determination of the range of hybridized Yellowstone cutthroat trout in the Lamar River, its major tributaries, and several other park waters.

- documentation of the status and movement patterns of grayling originating in Grebe and Wolf lakes of the Gibbon River system. More than 300 grayling are now tagged in the Gibbon River, and much of our current understanding of grayling distribution within the Gibbon River is due to the efforts of the flyfishing volunteers.

Another highlight of the 2004 field season was the initiation of a hook-type study, in which half of the volunteer anglers fished with barbed hooks, and the others with barbless hooks. The study will be continued in 2005, but preliminary results indicated no difference among hook types for injuring fish or causing mortality.

Under this incredibly successful program, 68 volunteer anglers from across the United States traveled to the park to participate as an active component of the Aquatics Section. Volunteers experienced many fisheries issues first-hand, and the biological data collected will assist in our understanding of the park's fisheries.


NPS/BILL VOIGT


JOANN VOIGT

Top: *The Yellowstone Volunteer Flyfishing Program brings anglers from across the country together to address the park's fisheries issues.*

Bottom: *During 2004, 68 anglers participated in the Volunteer Flyfishing Program, and information was obtained from many locations throughout the park.*

Long-term Volunteer Assistance

The Aquatics Section recruits long-term (more than 12 weeks) volunteers from the Student Conservation Association and other sources (see Appendix iii). Volunteers stay in park housing at Lake, and work a full-time schedule similar to paid National Park Service seasonal staff. All aspects of the Aquatics Section greatly benefit from both long- and short-term volunteer support. In 2004, a total of 103 volunteers dedicated 4,441 hours to Aquatics Section activities.

NPS/PAT BIGELOW

Smallcraft operator Don Wethington practices water rescue techniques with fisheries staff.

Educational Programs

Aquatics Section staff continued to provide a variety of short-term educational programs for visiting schools and other interested groups, with an emphasis on native fish conservation. The staff also provide for training in Motorboat Operator Certification and American Red Cross certification in First Aid and CPR for employees of Yellowstone National Park as well as other agencies.

Collaborative Research

The Yellowstone Center for Resources, through the Aquatics Section, provides both direct and indirect support for collaborative research with scientists at other institutions, primarily universities. These studies address some of the most pressing issues faced by National Park Service biologists and other regional managers of aquatic systems.

Projects by Graduate Students

Graduate Student: Julie Alexander (Doctor of Philosophy candidate).
Committee Co-Chairs: Dr. Billie Kerans and Dr. Todd Koel, Department of Ecology, Montana State University.
Title: Detecting *Myxobolus cerebralis* infection in *Tubifex tubifex* of Pelican Creek, Yellowstone National Park.

Graduate Student: Patricia Bigelow (Doctor of Philosophy candidate).
Committee Chair: Dr. Wayne Hubert, U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming.
Title: Predicting lake trout spawning areas in Yellowstone Lake as a part of the native Yellowstone cutthroat trout preservation program in Yellowstone National Park.

Graduate Student: Lynn Kaeding (Doctor of Philosophy candidate).
Committee Chair: Dr. Daniel Goodman, Department of Ecology, Montana State University.
Title: Comprehensive analysis of historic and contemporary data for the Yellowstone cutthroat trout population of Yellowstone Lake.

Graduate Student: Silvia Murcia (Doctor of Philosophy candidate).
Committee Co-Chairs: Dr. Billie Kerans and Dr. Todd Koel, Department of Ecology, Montana State University.
Title: Relating *Myxobolus cerebralis* infection in native Yellowstone cutthroat trout *Oncorhyncus clarki bouvieri* with environmental gradients at three spawning tributaries to Yellowstone Lake in Yellowstone National Park.

Graduate Student: Amber Steed (Master of Science candidate).
Committee Co-Chairs: Dr. Al Zale, U.S. Geological Survey Cooperative Fisheries Research Unit, and Dr. Todd Koel, Department of Ecology, Montana State University.
Title: Spatial dynamics of Arctic grayling in the Gibbon River, Yellowstone National Park.

Graduate Student: Lusha Tronstad (Doctor of Philosophy candidate).

Committee Chair: Dr. Robert Hall, Department of Zoology and Physiology, University of Wyoming. **Title:** The ecosystem consequences of invasive lake trout in Yellowstone Lake and tributary streams.


NPS/TODD KOEL

Cub Creek in spring 2004 following the East Fire of August 2003.

Other Research and Collaboration

The Aquatics Section continued to support a variety of other research projects in Yellowstone National Park. Of special mention is the research by the Great Lakes WATER Institute, University of Wisconsin at Milwaukee; Marquette University, Milwaukee; the U.S. Geological Survey, Denver; and Eastern Oceanics, Connecticut. Scientists from these institutions maintain a laboratory at Lake, outfit the Aquatics Section boat the *Cutthroat* with a submersible, remotely operated vehicle, or ROV, and study the physical, chemical, and biological characteristics of Yellowstone Lake, especially associated with hydrothermal vent systems.

Cutthroat Trout Broodstock Development

Wyoming Game and Fish employees collect a limited number of Yellowstone cutthroat trout gametes from the Yellowstone River at LeHardys Rapids. Gametes are used for enhancement of the native Yellowstone cutthroat trout broodstock (now located at Ten Sleep, Wyoming) and restoration activities in Montana and Wyoming. As an added benefit for Yellowstone fisheries, each year, age-zero Yellowstone cutthroat trout from the broodstock (LeHardys Rapids origin) in Wyoming are returned to the park for whirling disease exposure studies.

Acknowledgments

Much-appreciated administrative support for the Aquatics Section was provided by Becky Wyman, Barbara Cline, Melissa McAdam, Joy Perius, and Colleen Watson, with special thanks to Denice Swanke for all of her assistance and great amount of patience when working with the fisheries staff at the Lake office.

Many additional dedicated individuals from within Yellowstone National Park have contributed to the success of Aquatics Section activities; unfortunately we cannot mention them all here. However, we would like to especially thank Dave Hill, Earl McKinney, Susan Ross, Bruce Sefton, Melinda Sefton, Art Truman, Mark Vallie, Lynn Webb, and Dave Whaley from Lake Maintenance; Rick Fey, Michael Keator, Dave Phillips, Brad Ross, Steve Swanke, Boone Vandzura, and Kim West from South District Rangers; and Dave Elwood, Monte Simenson, and Wally Wines from Ranger Corral Operations.

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- Federal Highway Administration, Park Roads and Parkways Program
- Greater Yellowstone Coordinating Committee
- National Park Service, Recreational Fee Demonstration Program
- National Park Service, Inventory and Monitoring Program, Vital Signs Monitoring Program
- National Partnership for the Management of Wild and Native Coldwater Fisheries, Whirling Disease Initiative
- Yellowstone Association
- Yellowstone Park Foundation

We would like to extend special thanks to the Yellowstone Park Foundation and the many private individuals that have graciously provided support for our critical fisheries projects in the park.

S. Thomas Olliff, Natural Resources Branch Chief; Wayne Brewster, Deputy Director; and John Varley, Director, Yellowstone Center for Resources, provided guidance and support for the Aquatics Program.

We also thank the many volunteers who have dedicated their time and also a great deal of other expense to our Aquatics Section. Without them, much of what we do in our programs would not be possible.

Flyfishing anglers from Trout Unlimited, the Federation of Fly Fishers, the Henry's Fork Foundation, and many other organizations in the region and throughout the United States contributed hundreds of hours of time and costs associated with travel to our Volunteer Flyfishing Program; for that we are extremely grateful.

Through collaboration with the U.S. Fish and Wildlife Service's Bozeman Fish Health Laboratory, the U.S. Geological Survey's Western Fisheries Research Center in Seattle, the Department of Ecology at Montana State University, the Montana Department of Fish, Wildlife and Parks, and the Wyoming Game and Fish Department, we have been able to learn a great deal about whirling disease in the Yellowstone Lake basin. We thank all the individuals from these agencies for their kind support.

The Aquatics Section is extremely grateful for the assistance provided by David Weston, Dr. Mike Wells, Dr. Dan Shaffer, and the dedicated students of the Montana State University College of Engineering lake trout crisis senior design project.

Information on annual cutthroat trout spawning migration surveys and bear use of Yellowstone Lake tributaries (Figure 6) was provided by Kerry Gunther of Yellowstone National Park's Bear Management Office and Daniel Reinhart, Patrick Perrotti, and Eric Reinertson of the park's Resource Management and Visitor Protection Division.

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Appendices

Appendix i. Fish Species List

Native (N) and introduced (non-native or exotic, I) fish species and subspecies known to exist in Yellowstone National Park waters including the upper Missouri (Missouri, Madison, and Gallatin rivers), Snake River (Snake), and Yellowstone River (Yell R.) drainages.

Family	Common Name	Scientific Name	Status	Missouri	Snake	Yell R.
Salmonidae	Yellowstone cutthroat trout	*Oncorhynchus clarki bouvieri*	Native	I	I	N
	Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	Native	N		
	Finespotted Snake River cutthroat trout	*Oncorhynchus clarki behnkei**	Native		N	
	Rainbow trout	*Oncorhynchus mykiss*	Non-native	I	I	I
	Mountain whitefish	*Prosopium williamsoni*	Native	N	N	N
	Brown trout	*Salmo trutta*	Exotic	I	I	I
	Eastern brook trout	*Salvelinus fontinalis*	Non-native	I	I	I
	Lake trout	*Salvelinus namaycush*	Non-native		I	I
	Arctic grayling	*Thymallus arcticus montanus*	Native	N		I
Catostomidae	Utah sucker	*Catostomus ardens*	Native		N	
	Longnose sucker	*Catostomus catostomus*	Native			N
	Mountain sucker	*Catostomus platyrhynchus*	Native	N	N	N
Cyprinidae	Lake chub	*Couesius plumbeus*	Non-native			I
	Utah chub	*Gila atraria*	Native	I	N	
	Longnose dace	*Rhinichthys cataractae*	Native	N	N	N
	Speckled dace	*Rhinichthys osculus*	Native		N	
	Redside shiner	*Richardsonius balteatus*	Native		N	I
Cottidae	Mottled sculpin	*Cottus bairdi*	Native	N	N	N

* Scientific name suggested by Behnke (2002), *Trout and Salmon of North America* (New York: The Free Press), and not currently recognized by the American Fisheries Society.

Appendix ii. The Waters of Yellowstone (adapted from Varley and Schullery, 1998)

Size of the park	898,318 hectares
Water surface area	45,810 hectares (5% of park)
Number of lakes	150
Lake surface area total	43,706 hectares
Number of fishable lakes	45
Yellowstone Lake surface area	36,017 hectares
Number of streams	>500
Stream length total	4,265 kilometers
Stream surface area total	2,023 hectares
Number of fishable streams	>200

NPS/DAN MAHONY

Snake River.

NPS/TODD KOEL

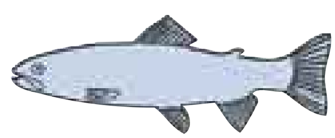
Volunteer Flyfishing Program coordinator Bill Voigt examines a fish caught on Slough Creek by Chessie Thacher of the Yellowstone Park Foundation.

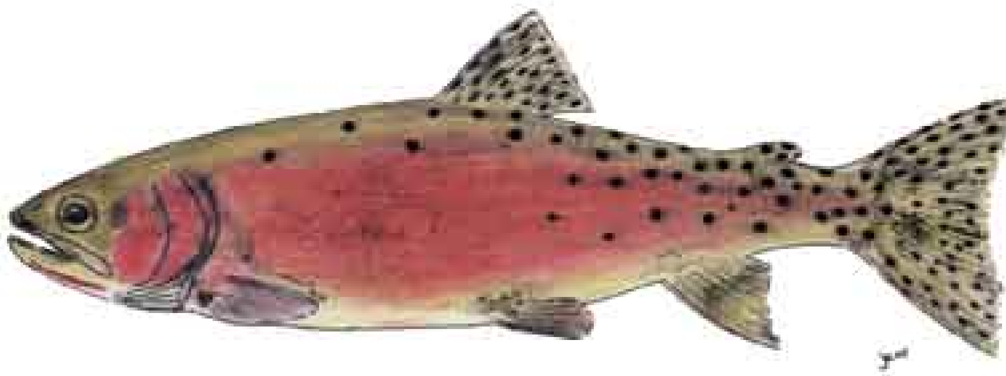
Appendix iii. Long-term Volunteers, 2004

Name	Period of Involvement (mm/dd/2004)	Hours
Allen, Hayley	09/06–11/27	480
Blakney, Jason	08/08–10/30	480
Cook, Michelle	08/23–11/13	480
Dixon, Chris	03/16–04/30	296
Fisher, Christine	06/01–08/02	280
Hutchinson, Hunter	08/27–10/30	360
Merryman, David	05/16–08/07	480
Varian, Anna	05/16–10/30	845
Voigt, JoAnn	05/25–08/21	149

Appendix iv. Seasonal Staff, 2004

Name	Period of Involvement (mm/dd/2004)
Anacker, Melissa	05/16–08/21
Anderson, Krisi	05/16–11/24
Bywater, Tim	05/25–08/21
Cook, Alice	05/26–08/21
Conley, Steve	05/16–08/31
Dixon, Chris	05/02–10/08
Facendola, Joseph	05/12–11/24
Fisher, Christine	08/03–10/30
Jones, Mike	05/02–10/08
Kavanagh, Maureen	05/09–10/30
Keep, Shane	05/02–10/08
Legere, Nicole	05/27–10/30
Olszewski, Brad	05/19–11/24
Rowdon, Barb	01/01–10/30
Sigler, Stacey	05/12–10/30
Voigt, Bill	05/25–08/21
Wethington, Don	05/02–10/30





JOE FACENDOLA

Yellowstone cutthroat trout.